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AUTOMATIC TARGET CUEING STUDY FOR HELICOPTER FIRE CONTROL. PHAS--ETC(U)
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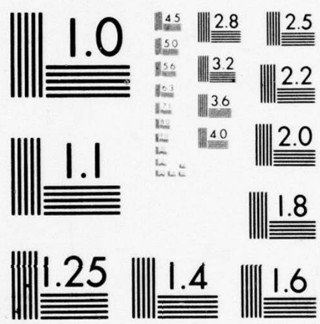

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Aerospace and Electronic Systems

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Statement of Work

AUTOMATIC TARGET CUEING STUDY

For

HELICOPTER FIRE CONTROL.

PHASE II.

Negotiation No. N-2323

15 May ~~15,~~ 1972

21p.

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Presented to

U.S. ARMY MATERIEL COMMAND
Frankford Arsenal
Philadelphia, Pa.

By

WESTINGHOUSE ~~ELECTRIC CORPORATION~~ Defense electronic systems center
SYSTEMS DEVELOPMENT DIVISION
BALTIMORE, MARYLAND

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1.0 INTRODUCTION

In March 1971, Westinghouse proposed a program to the U.S. Army Materiel Command, Frankford Arsenal, for improving target acquisition with FLIR systems in helicopters, using automatic cueing techniques. The improvement would make use of a digital image processor for automatic detection and recognition of targets. The processor would operate on the FLIR video signals. It would provide an alarm to the pilot/gunner to indicate the presence of specific classes of targets in the FLIR field of view. In addition, the location of the target in his display would be marked by visual cues.

The proposed test and development program provided for a flight test of an engineering model of an automatic cueing system within three years. It consisted of four distinct phases, as shown by Figure 1-1. The Phase I Feasibility Demonstration was initiated in October 1971, under Contract DAAA-25-72-C-0154. This program is presently on schedule. In accordance with Figure 1-1, work on Phase II should begin in July 1972. This document offers in Section 2 a proposed statement of work for the Phase II tests. Considerations involved in the construction of the engineering model are given in Section 3, and for the flight test, in Section 4.

The Phase II program would be managed and staffed by the personnel presently involved in Phase I tests.

A review of available performance data for FLIR systems (for example, the STANO tests at MASSTER) indicates that target acquisition capability is seriously reduced by such problems as operator workload, concern for aircraft safety, and eye fatigue. By providing an alarm when potential targets are in view, and by reducing search time within the display, it is believed that the

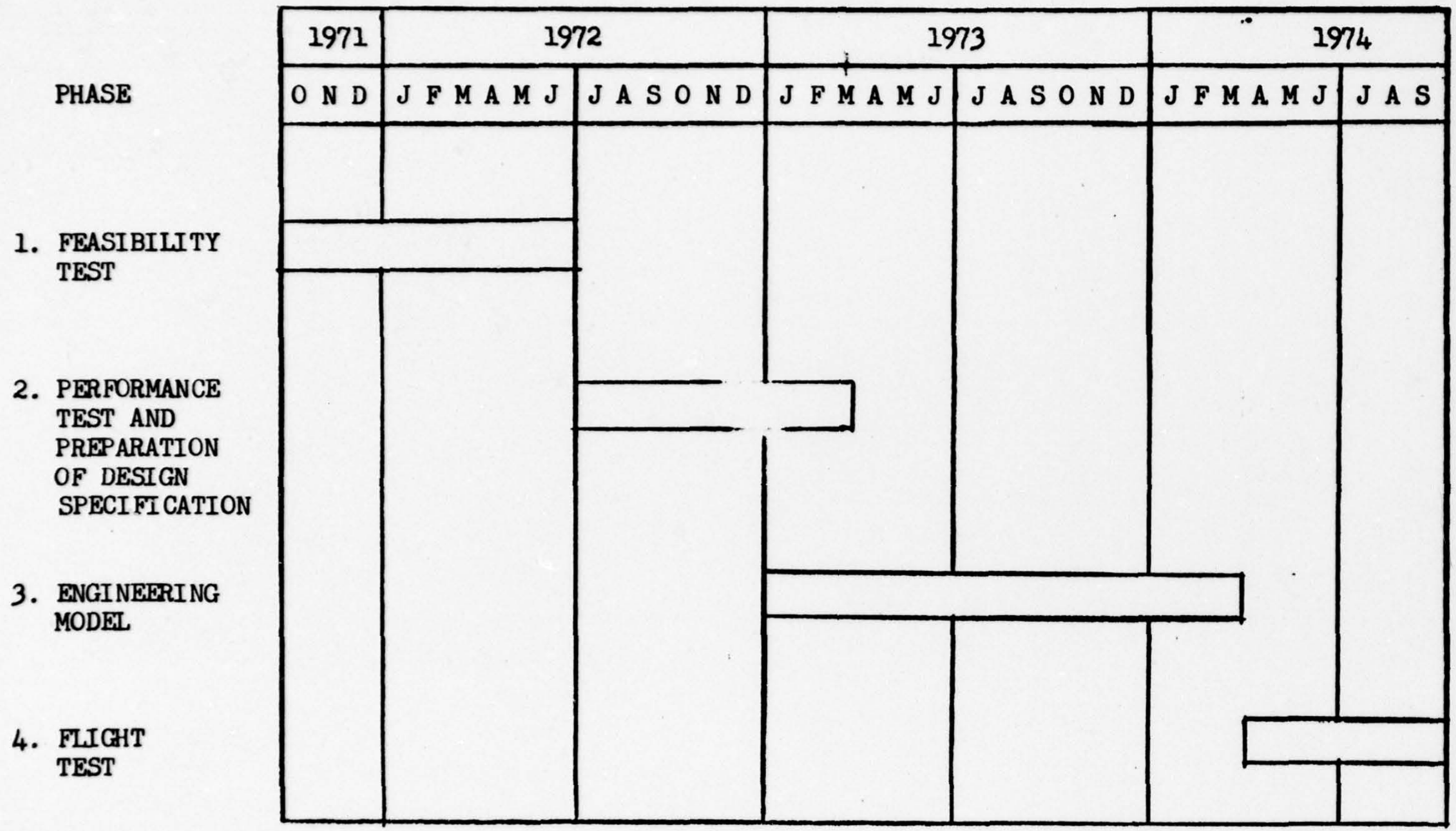

Figure 1-1 Three-Year Test and Development Program - Automatic Cueing for Helicopter Fire Control

automatic cueing system will provide improvements in both target acquisition efficiency and range.

2.0 PHASE II - PERFORMANCE TEST AND PREPARATION OF DESIGN SPECIFICATIONS

The Phase II test program is a logical extension of the work on Phase I. Six tasks are proposed, as shown by Figure 2-1. For each of these tasks the required man-hour estimates are indicated on a monthly and overall basis. The proposed duration of the program is nine months.

The first task is the preparation of a detailed test plan. This plan will take into account the latest information available with regard to:

a. Test results in Phase I;

b. Availability of FLIR imagery for Phase II tests;

c. Program objectives, such as choice of target classes, as defined by the Army program monitor.

Tasks 2 and 3 cover the continued evaluation of image processor performance in target detection/recognition by computer simulation. Acquisition and processing of imagery will be carried out under Task 2, which will also apply to the human factors evaluation under Task 4. Performance of the simulation tests will be conducted under Task 3. A detailed description of present plans for this test is given in Par. 2.1.

The ultimate value of automatic cueing depends on the improvement in overall system performance which will be realized with its use. This includes a comparison of the performance of the helicopter crew with and without cueing. Task 4 proposes a human factors evaluation to obtain this comparison. The proposed program is discussed in Par. 2.2. Westinghouse experience with human factors evaluations on other weapons delivery programs is also enumerated.

Design considerations for the engineering model of the cueing system will be investigated under Task 5. This work continues a preliminary evaluation

TASKS	MONTHS - ARO 1	2	3	4	5	6	7	8	9	TOTAL HOURS Eng.	Prog.	Comp.	T.P.
1. Prepare Test Plan	80/									80			
2. Acquire and Process Imagery	80/40	80/40	80/40	80/40						320	160		
3. Statistical Test Program	80/ 80 (2)	80/ 80 (4)	80/ 80 (4)	120/ 100 (5)	120/ 100 (5)	160/ 100 (5)	160/ 100 (5)	160/ 80 (5)	160/ 80 (5)	1120	800	(40)	
4. Human Factors Evaluation		80/	80/	80/	80/	110/	160/	160/		750			
5. Preparation of Design Specification for Engineering Model	80/	80/	80/	100/	100/	100/	100/	80/	80/	800			
6. Progress Reports		△	△	△	△	△	△	△	△ 80/ 80 △ Final Report	80			80
Total										3150	960	(40)	80

Figure 2-1 Phase II - Performance Test and Preparation of Design Specification

under the Phase I studies. In addition to the requirements for the digital image processor itself, attention must be given to the FLIR interface, including the sensor outputs and the display modifications. Furthermore, implementation necessary for successful scoring of the flight test results must be considered. The discussion of Task 5 effort is contained in Par. 2.2.

In accordance with the practice carried out on Phase I, it is proposed to supply brief status reports on a monthly basis, followed by a comprehensive final report at the conclusion of the program.

2.1 Statistical Test Program

The objective of this task is to evaluate the performance of the digital image processor in sufficient depth to establish confidence in its capability. The criteria for processor evaluation are its ability to detect or recognize targets of interest which are present in the field of view, and its ability to ignore other signals. Both detection and recognition are of interest, defined as follows:

Detection - location of a consistent local change in image density;

Recognition - assignment of a class designation, such as truck, tank, etc., based upon available image shape information.

Other factors of interest in the test program include the choice of target classes, the effect of image quality on performance, and a determination of the number of samples to be tested.

Choice of Target Classes

The target classes under consideration during the Phase I test are:

- o Vehicles, i.e. cars, civilian trucks.
- o Airplanes, sitting on the ground.
- o Boats

A recent Army test program involving route and area sector searches provides other candidate target classes. They include

- 2-man bunkers
- Personnel, i.e. 7-man groups
- Tanks
- Trucks, i.e. ¼-ton and 2½-ton
- Boats.

Other possible targets are:

- Bridges
- AA sites.

The final selection of target classes depends upon the available imagery. Classes should be selected which are represented in the imagery in sufficient quantity to obtain a high level of confidence in the test results, as detailed later.

Imagery Considerations

There are at least two possible forms of FLIR imagery that can be used. A film taken of the display is one source. However, available film speed may require high display contrast, with resulting loss of original signal quality, i.e. resolution and contrast of the FLIR video. Consequently, a recording of the video signal would yield a more accurate representation of the sensor system. Ultimately, the video signal will be the input to the actual hardware of the cueing system. Thus it is more desirable if a video signal recording can be obtained.

Image Processor Training

Just as the operator/gunner must be trained to recognize targets on a display, the digital image processor must be trained to recognize targets in its input signal. In practice, a set of images containing the targets is presented to the processor. A set of non-target images is also presented so that the system can learn to reject these cases.

The greater the number of samples in this training set, the better the system can recognize targets. However, with a fixed number of target images available, a practical division of sample images is to set aside one-half of the images for processor testing.

Image Processor Test

The substance of the test program is contained in this test phase. The processor is presented with a large number of windows or scenes, some of which contain targets. The system then searches each scene and reports, or cues, target detections/recognitions.

The system's ability to detect and recognize targets in these area scenes is measured by its detection/recognition percentage. Since for any given series of test runs the D/R percentage is a statistically varying estimate, it must be considered in terms of its "confidence interval", and "confidence level". For example, if a test series of 100 runs produces a D/R percentage of 80%, then it can be computed that the range 71% to 88% contains the true D/R rate for the system, with 95% certainty.[*1]

A secondary measure of system effectiveness is its Type-I error rate. This is the rate at which the system reports a detection/recognition in a new scene, when no target is present. If an operator were doing the target searching, it would be the rate at which he incorrectly reports a target recognition. As

*1 Highleyman, W., "The Design and Analysis of Pattern Recognition Experiments", Bell System Technical Journal, March, 1962.

in the case of the D/R percentage, the Type-I error rate must be described in conjunction with its level of confidence.

Number of Test Samples

It is the desired level of confidence in the test results that determines the desired number of samples to be used in the test.

Considering first the detection/recognition rate, assume for example that the estimated percentage will be approximately 80%. Then with 95% confidence the following can be said:

- o 65% < D/R < 92% with 30 samples
- o 66% < D/R < 90% with 50 samples
- o 71% < D/R < 88% with 100 samples

Therefore the greater the number of test samples (target scenes) the more accurate the D/R percentage number.

Similarily for the Type-I error rate, assume for example that a measured error rate of 1% occurs. Then three examples for the 95% confidence intervals are:

- o 0% < Type-I error < 5% with 100 runs
- o 0% < Type-I error < 4% with 250 runs
- o 0% < Type-I error < 2% with 1000 runs.

As a compromise between confidence levels, availability of sample imagery, and program cost, it is proposed that tests be carried out for each target class using 50 target scenes and 250 non-target scenes. An additional 50 target scenes will be required for training.

At least four target classes can be completed during Phase II if sufficient FLIR imagery can be obtained. Completion of the detailed test plan will be the initial task in the Phase II program. Imagery can be either films of FLIR displays, or recorded video signals. Video signals are preferred, as mentioned earlier; however, recordings which are carried out in other than normal TV format may require additional effort for conversion to image form.

2.2 Human Factors Evaluation

This paragraph describes human factors experiments for evaluating the effects of automatic cueing of electro-optical displays. FLIR imagery will be used to determine the differential performance between unaided and aided detection/recognition. The value to the pilot/gunner is realized by the reduction in search area and screening of imagery under high noise and clutter conditions. Reduced search area serves to reduce detection/recognition times, the effective result of which is to increase target acquisition range and thereby enhance the probability of mission success.

Factors to be considered in the design of the experiment are the generation and presentation of stimulus materials, the operator and task variables, response measures and analytical approach, and experimental design procedures. Final determination of the experiments will be accomplished during the early months of the Phase II program.

Stimulus Materials

The test mechanization will be to present filmed or recorded FLIR imagery on a TV formatted display. The objective will be to compare operator and system response for cued detection/recognition versus unaided detection/recognition. Electronic cursors will be superimposed on the FLIR imagery to represent cues. The occurrence of these cursors will be determined from the performance of the image processor on the same imagery in simulation tests. In order to measure operator response, a hand-stick controlled cursor will be positioned by him on the target, and a thumb-switch depressed to indicate the time of target acquisition. Although specific response mechanization and cursor display procedures have not yet been defined, the basic detection recognition aided and operator cursor control mechanization procedures will be implemented within an operational "real-world" context. Consideration will be given to the occurrence of successive single targets as well as to multiple targets. Determination of this occurrence will depend upon pre-experimental imagery analysis (number and types of targets and time-of-target within field-of-view) in conjunction with operator response measures requirements.

Visual-Display Considerations

Operator visual-display performance factors will be considered with respect to display raster, resolution, contrast and target angular subtense at the display. Other factors such as cursor control sensitivities, cursor size, and "attention-getting" qualities will also be considered. For example, for cursor-designated (aided) presentations, a flickered presentation will be evaluated for possible incorporation. Previous in-house multi-sensor display experimentation has indicated the hot-spot "attention-getting" qualities of IR-inserted (into TV) flicker presentations. Significant to detection recognition performance are the distinguishing features of a target in relation to the characteristics of the background. A flickered cursor-designator could provide enhanced operator responsiveness while preventing continuous obscuration of potentially important contextual background information. Also to be considered, however, are factors such as flicker rate (2Hz used in above experimentation) and potential flicker annoyance factors.

Response Measures

The experimental approach will involve other detailed considerations such as response measures (dependent variables), experimental design and procedures and treatment of data. Response measures for comparing aided versus non-aided detection/recognition performance are detection/recognition time, completeness and accuracy. Response times, depending upon taped FLIR imagery acquisition data, could be converted into relative detection/recognition range performance differences between aided and non-aided presentations. Time data could also be applied with respect to search time differences as a function of the different techniques. Completeness data (number correct/number possible) and accuracy data (number correct/number of attempts) will also be considered response measures. The accuracy data will yield false alarm responses and when applied to an outcome matrix analysis can be used to derive detection/recognition probabilities as a function of the different techniques.

An outcome matrix is shown by Figure 2-2. In this matrix, the probabilities of correct responses are given by P (N,n) and P (T,t). Error probabilities are given by P(N,t) and P (T,n). The former , P (N,t) is an error of commission, or false alarm, while P (T,n) is an error of omission, or missed target. Since the column cells are mutually exclusive, (i.e., the observer reports a target is or is not present) the probabilities sum to unity.

Experimental Design Procedures

In order to effectively isolate and evaluate performance differences as a function of the variables involved, it is required that appropriate control be exercised through selection of an appropriate experimental design, e.g. factorial, treatment-by-subject, mixed etc. Included, as a portion of the test

Ground Truth

		No Target (N)	Target (T)
Response	No Target (n)	P (N,n)	P(T,n)
	Target (t)	P(N,t)	P(T,t)

Figure 2-2 Outcome Matrix

P(N,t) is read as the probability of reporting a target when no target is present plan, will be detailed experimental procedures for minimizing and allowing the isolation and analysis of subject variances. The experimental procedures will include subject instruction and familiarization requirements as well as experimental presentation ordering (e.g. counterbalanced versus randomized presentation). However, canned taped imagery will limit ordered sequencing unless retaped for specific presentation sequences.

Treatment of Data

Response time data will be treated by analysis of variance to define significant effect interactions of the variables studied. Data distributions will be analyzed for percentage response and recognition probability derivations will be generated for significant effect interaction. These data, in turn, will be analyzed to relate information derived for specific imagery presentations to applicable operational implications for "real-world" missions situations. Essentially, the analytical results will be structured, through experimental design application, to determine:

- the influence each variable exerts on the detection/recognition measures
- the combined variable interaction effects on detection/recognition measures
- the amount of variance due to subject variability and uncontrollable experimental conditions.

Westinghouse Experience in Human Factors Studies

The Westinghouse Simulation Laboratory has developed a hybrid computing facility capable of analog and/or digital operation in support of machine system interface experimental programs. Recent simulations and experimental efforts have involved the Multisensor Weapons Delivery System (real-time, synchronous, registered TV and IR imagery on a composite display with multiple mode signal enhancement techniques), PAVE SPIKE (air-to-ground manual rate-aided weapons delivery tracking studies) and PAVE LANCE (energy maneuverability display concept studies). Westinghouse has in-house flight experienced personnel who participate as subjects in our simulation experiments and who will be available for this study.

2.3 Preparation of Design Specification

The specific operational and interface requirements of a digital image processor which will add automatic target cueing capability to a FLIR system will be determined during Phase II. This is essential to provide a basis for the design and construction, during Phase III, of an image processor which will demonstrate automatic target cueing. Available FLIR systems will be studied to determine sensor and display interface requirements and to understand the operational modes of the FLIR and associated weapons which will be affected by automatic cueing.

The FLIR sensor array configuration, scan type, resolution achieved and the method of converting the image to video signals will determine the image data which is available to the image processor. The optimum point for sampling the sensor video will be studied. In the AN/AAQ-5 FLIR, for example, the sensor video might be obtained from the two multiplexer outputs. The offset rows of the detector array and the high data rate of the combined multiplexer outputs would require buffering at the processor input.

Special-purpose design is required for the image processor to achieve the required processing rates. However, the use of a general-purpose processor such as the Westinghouse Millicomputer will be considered for performing some recognition functions. Processing of a partial image during each frame time will be considered as a tradeoff against the hardware required.

The type of cueing signals to be used to mark identified targets on the FLIR display will be determined by the human factors study during this phase of the program. The need for an operator scoring system will also be studied. A scoring system might consist of a marker which can be phased over the target by the operator using a joystick with a push button to signal the time when he considers his marker on the target. A film record of the display could be used to evaluate the operators performance with and without automatic target cueing. Requirements for synchronizing and mixing symbols with the FLIR display video will be determined from the characteristics of the FLIR display.

Design specifications for the digital image processor will be based on the FLIR system which is to be used for testing the automatic cueing system.

3.0 PHASE III, ENGINEERING MODEL

An engineering model of the digital image processor with FLIR sensor and display interface equipment will be designed, built and tested during Phase III. This model will be designed to work in conjunction with the specific FLIR system which will be used for helicopter tests of the automatic target cueing system. A budgetary estimate of the cost of this system is $450,000 for the basic image processor, plus $50,000 for the sensor interface and $48,000 for the display interface, including cueing markers and an operator scoring arrangement for tests. The possibility exists for sharing the cost of developing the basic image processor with another branch of the service if the contracting agencies were to reach a satisfactory agreement.

The engineering model of the processor and its interface equipments will, in general, be constructed using standard integrated circuit packages on boards which plug into a mother plate. Automatic wiring techniques such as stitch wiring and wire wrap will be used for wiring the boards and mother plates. Using this type of construction, it is estimated that the processor will be packaged in a volume of approximately 6 cu ft., weigh about 190 lbs and would require about 1800 watts of power. It is projected that a production version using bare chip integrated circuits on multilayer substrates and compact power supply design could be packaged in about 1.3 cu. ft., would weigh about 80 lbs. and would have the same power requirements. Estimated cost for a processor of this type would cost about $50,000. For large scale production, the size, weight, power and cost could be further reduced by the development of LSI chips for the logic functions. It is estimated a processor using LSI chips could be produced for $5000. Production of sufficient volume to warrant an LSI design may develop from the combined military, government, and civilian applications for a digital image processor in extracting information from imaging sensors.

4.0 PHASE IV, FLIGHT TEST

Installation and checkout of the automatic cueing system can be accommodated at the Westinghouse Flight Development Laboratory. Target acquisition tests should make use of an appropriate test range, such as the MASSTER range at Ft. Hood.

The Westinghouse Flight Development Laboratory is equipped to provide maintenance modification flight crews, and administrative support for any military or commercial aircraft leased or bailed to the activity during a flight evaluation or development phase of the contract.

F.D.L. is currently staffed with four pilots, one of which was assistant director of the Navy Test Pilot School at N.A.T.C., Patuxent River and has experience in the UH series helicopters. The project engineering section includes airborne observers and wiring modification engineers utilized in the modification and flight phases as needed. The maintenance and inspection group number approximately 30 and provide flight line level support up to and including major inspections short of depot level items.

The F.D.L. facility is located adjacent to Baltimore Friendship Airport and next to the main Westinghouse Friendship Plant. All engineering and instrumentation facilities are available for support during flight development phase.

The facility has been conducting flight test activities since January 1952, which have included modifying and flying all types of military aircraft up to B-29 size. Some recent helicopter programs that have been conducted here are the "Acoustic Pod" for various aircraft including the AH-1G. The "Helicopter Supported Radar" program for the Airforce in the UH-IE involved installation and flight check of a large battlefield surveillance radar system with 10 ft rotating antenna suspended below the aircraft and hydraulically retracted for landing. The "LAMPS" program for the Army in UH series helicopters was recently completed.

The proposed flight development phase for this program would involve approximately six months for aircraft and system modification, development (Category I) flights, and demodification prior to return of the aircraft. The recommended procedure would be to bail the aircraft for the required period, request G.F.E. fuel, specialized ground support and flight equipment, and spares allowance (or support from nearby Army activity for spares) and mechanic and pilot training as needed. The flight test phase would be of a Category I type with a breadboard system and approximately two flights per week depending on system repairs and flight analysis. The development phase would insure that the system would be ready for "Range Evaluation" flights by the Army at their selected test area. The contractor could utilize Aberdeen Range for preliminary development as well as other nearby target areas to insure system compatability before detailed range tests.